California Energy Commission
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HPCBS

High Performance Commercial Building Systems

Report on metrics appropriate for small commercial customers (E2P2.1T3a) & Report on selection of case study sites (E2P2.1T3b)

Element 2 – Life Cycle Tools
Project 2.1 – Benchmarking and Performance Metrics
Task 3

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PIER Public Interest Energy Research
CALIFORNIA ENERGY COMMISSION

BERKELEY LAB

High Performance Commercial Building Systems
PIER Program

Element 2: Life-Cycle Tools

Task 2.1.3 Benchmarking Performance Assessment for
Small Commercial Buildings

Year One Reports:
Selection of Case-Study Sites
Appropriate Metrics

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Selection of Buildings for Case Studies

Introduction

The intent of Task 2.1.3 is to determine how a small sample of people involved in operating buildings can make use of benchmarked energy-consumption data. To elaborate, until very recently benchmarking data have been the province of energy analysts and not those who operate businesses and pay energy bills. Examples of such data include the surveys of residential and commercial buildings performed by the U.S. Department of Energy's Energy Information Agency (EIA). As part of Element 2, other researchers (at LBNL) are developing a Web-based benchmarking tool that will permit a user to compare an energy-use intensity (EUI, annual energy consumption normalized by floor area) to the consumption of similar buildings. This tool, Cal-Arch, will include CEUS (Commercial End-Use Survey) data sets for California buildings and is intended to appeal to:

- Energy service companies and performance contractors
- Full-service control companies
- Organizations interested in including energy performance in building appraisals
- Designers
- Energy managers and building owners
- Software developers and energy consultants

For Task 2.1.3, the focus is on building owners. Are they interested in benchmarks? How will they use them? Are they interested in sharing energy information with others in similar positions, as a means of comparing notes and determining further steps to control energy costs?

A second but still crucial element of Task 2.1.3 is the application of advanced technology to obtain energy information at selected sites. To compare energy consumption at a particular building to an EUI-based benchmark requires nothing more than a year of energy bills. The user of a benchmarking tool then must assess why the EUI for the site in question differs from that of supposedly comparable buildings. Longer hours of operation? Special equipment? More widgets produced? Not yet able to afford an overdue lighting retrofit? End-use information can be used to pinpoint areas of relatively high energy consumption. If a benchmark includes end-use information, then end-use information for the site in question is essential.

In small non-residential buildings (retail, restaurants, schools), obtaining end-use information or even time-of-use whole-building information requires metering not typically installed. The cost of such metering is widely perceived by energy analysts to be a barrier. It is not clear that the additional information would in fact be effectively used, in ways that would generate savings that would provide a decent return on the metering investment.

MIT is developing a high-speed meter capable, at least in some cases, of disaggregating a measured electrical current into components that can be assigned to particular pieces of equipment. This Non-Intrusive Load Monitor (NILM) provides not only time-of-use information at the measurement point (whole building or a major portion of particular interest) but also provides some amount of information about equipment operation, including on/off cycling, an estimate of energy use, and detection and possibly diagnosis of equipment faults. Please see Luo (2001), Luo *et al*. (2002), Norford and Leeb (1996), Norford *et al*. (2000, 2002), Shaw and Leeb (1999) and Shaw *et al*. (1998, 2002) for more information. The intent of Task 2.1.3 was to include in the selected test buildings one or more for which it would be possible to install a NILM. It was initially planned to select a population of about ten buildings and make use of energy bills in all, supplemented by time-of-use metering in two or three and the NILM in one or two.

A third element in Task 2.1.3 is the use of the NILM for measuring equipment-level performance in sufficient detail to detect faults. This element was not included in the original proposal but it is desirable to offer as much value as possible in a particular research project. For this work, the targeted equipment is roof-top packaged air conditioners. These are widely used and there is considerable recent interest in developing low-cost equipment that can be used to diagnose faults that would compromise cooling output or increase power consumption. A survey of commonly occurring faults in roof-top units and an approach to detecting these faults is presented in Breuker *et al*. (2000).

Based on the three central issues, MIT researchers considered different sets of candidate buildings, as will be discussed in the next section of this report. Note that the three issues do not uniquely specify a single type of building. While it was initially proposed to work in small commercial buildings (retail), it will be shown that a more suitable population of buildings is K-12 schools. Schools are very different from retail businesses, of course, but there is substantial societal benefit to improving the energy performance of either, or both.

Candidate Building Populations

A number of buildings were visited to assess their suitability for field research. These buildings included:

- A community college system in Oakland that consists of three campuses, of which two were visited;
- Three small commercial buildings in East Palo Alto: an auto parts and auto engine-repair store, a grocery, and a funeral home;
- Commercial buildings in the Presidio;
- Four public schools in theWest Contra Costa Unified School District (WCCUSD).

The public schools were considered the most suitable for continued research, for several reasons:

- Strong support of an energy-service consultant, who arranged contacts at all sites listed above except the community-college system. She is participating in an effort to improve the energy efficiency of schools in the district and is very helpful in representing MIT’s interests to school officials and in describing current energy-upgrade activities.

- PG&E has provided energy-consumption data needed for establishing an internal benchmark (consumption for all schools within the district). This saves MIT the step of needing to collect data to prepare the benchmark and leverages PG&E's efforts.

- Support of school officials for installation of monitoring equipment. It is hard to underestimate the value of this support. Here the issue centers on the second element in the research, as noted above: use of the NILM. Because the NILM is in a development phase, its installation and upkeep is not as streamlined as it will need to be if it is to attract the interest of commercializers. While MIT considers the current status of the NILM to be quite promising, it still requires considerable effort to install and maintain. This effort involves examination of building electrical plans to size current transducers; on-site inspection of building wiring to determine an appropriate location for the meter and to assess difficulties in placing current transducers; hiring of a licensed electrician; and installation of a communications line used to update the programming in the NILM (which runs on a personal computer using the Linux operating system and functions as an Internet site) and to download data. While communications can in principle be provided via an Internet node in an established network, and such a connection has proved to be highly reliable in limited field tests to date, it is often very difficult to obtain an address on an established network. Approvals may be withheld due to security concerns and even when on-site personnel are willing to install a network connection it may in practice be impossible to penetrate existing firewalls. When a network drop cannot be provided, it is necessary to install a DSL line. MIT's experience to date has been that the active cooperation of on-site personnel is essential.

- Interest of school officials in understanding and reducing energy consumption. The first element of this study is an assessment of how energy users could make use of benchmarks. A null result would in principal be interesting: owners or managers of certain types of buildings may feel that they have no time or skill in comparing their energy bills against consumption data for supposedly similar buildings. MIT considers it a better use of CEC-provided research funds if the targeted set of owners or managers in fact does show a willingness to make use of benchmarks. One drawback in using the schools is that there is a single set of personnel responsible for all schools in the district. As a result, the experiment will not include in itself opportunity for managers to talk to each other about energy bills and benchmarks. MIT will attempt to learn about communications among school districts and whether energy consumption is discussed across school-district boundaries.

- Potential near-term extensibility. The consultant who directed MIT to the WCCUSD is working in other public school districts in California. Data analysis techniques, assessments of end-use energy consumption, and conservation strategies that come out of the work at WCCUSD can be readily transferred.

- Opportunity to assess whether the NILM can monitor the performance of rooftop air-conditioning units. One of the schools targeted for metering has this equipment.

- Opportunity to test a load-reduction strategy. Control of loads during peak periods has recently been of particular interest in California. Load control in aggregates of buildings is a task assigned to MIT under Architectural Energy Corporation's prime contract with CEC. In the same school where MIT will monitor a rooftop unit, school officials are already running a fan at night to pre-cool a classroom, in an attempt to reduce on-peak use of the air conditioner. It is worthwhile to monitor the performance of the existing control strategy. Further, it is likely that there is room for improved control of the fan and air conditioner, to minimize overall operating cost.

- Societal benefit. As noted above, public schools, like small commercial buildings in low- or moderate-income neighborhoods (as distinct from more affluent businesses that can afford a wide range of for-hire energy services), can benefit from energy services that would otherwise not be affordable. These services include benefits from participating as test sites in CEC-sponsored research and benefits from the knowledge and technologies generated from this research.

The community college campuses consist of a small number of classroom buildings. As was discovered in a detailed examination of metered data at MIT, it is difficult to match meter accounts with physical space. It appears that there is a similar issue at the community college campuses, where metering accounts and buildings do not match up in on a one-for-one basis. In addition, it would be necessary to construct a benchmark database from other community colleges in California.

The small businesses in East Palo Alto were offered energy audits as part of another program. Owners were willing to take advantage of opportunities to reduce energy bills, but were also very much focused on meeting the needs of their customers. Reaching a larger population (ten buildings, as a target) and working with individual shop owners was considered to be more difficult than working with school officials. MIT has had recent experience in installing and maintaining a NILM in a nearby fast-food restaurant. It would be all but impossible to install NILMs in similar businesses in California without local support.

Buildings in the Presidio are controlled by a Trust and are leased to commercial and residential tenants. The non-profit Presidio Alliance seeks to support occupants and the Trust by identifying energy-efficiency opportunities, including energy monitoring. MIT considered the schools to be more in need of assistance at this time.

Monitoring Plan

MIT will work with school officials to help them make use of benchmark data for their buildings (again, the benchmark for any given school is the data set for all the schools in the district). Further, MIT is now installing four NILMs and three data loggers (to provide supplemental information and to assess the performance of the NILMs) in two schools: Pinole Middle School and Hanna Ranch Elementary School. In Pinole, a NILM and a data logger are being installed at the service entry point for electrical power and for one wing of classrooms, where there will be a demonstration of improved lighting and heating equipment. In Hanna Ranch, a NILM and a data logger are being installed in an air-conditioned classroom and another NILM is being installed at the service entry point. All data loggers are capable of measuring electrical current from 16 current transducers and combining the current data with a single-point voltage measurement to determine device-level electrical power.

Benchmarking Metrics for the schools of West Contra Costa Unified School District

A benchmarking study is being conducted on the 49 schools of the West Contra Costa Unified School District (WCCUSD). It covers 39 elementary, five middle schools and five high schools. The schools range in size from 22,858 to 226,510 square feet. The total square footage covered by the analysis is 3,244,861 and the total annual energy bill is approximately $1,798,460.

The energy benchmark study is being performed to assess the status and efficiency of the current energy usage and to find opportunities in which significant energy savings can be achieved. Benchmarking can be performed by comparing within the sample group itself or with other sample groups, such as the schools in the nation or a specific region.

The energy consumption and billing data are provided by the Pacific Gas & Electric Company (PG&E 2000a) which is the utility supplier of the school district. The PG&E report also provides benchmarking based on median energy usage for schools within the district. The raw data for both electricity and gas are given in Table A1 in the Appendix. The national data for comparison are taken from the 1995 Commercial Buildings Energy Consumption Survey by the U.S. Department. of Energy (DOE) (EIA 1997). The regional data are from the 1999 Commercial Building Survey Report by PG&E (1999).

Electricity Analysis

Electricity consumption is usually the first concern in energy analysis. Figure 1 shows the annual electricity consumption of each school. Figure 2 shows the resulting dollar cost. Unit cost per kWh varies depending on the location, but can be averaged to about $0.105/KWh. From the graph, it can be understood that the high schools use more electricity than the middle schools and that the middle schools use more power than the elementary schools, although Downer elementary school is an exception. This general trend makes sense considering that secondary schools tend to have more class hours and after-school activities than primary schools and that they have more students and larger buildings compared to the primary schools. Student enrollment data are given in Table A2 in the Appendix.

Considering that different schools have different area and number of students, it is not fair to compare the total amount of energy consumed by each of them. The annual electricity usage is often normalized in terms of energy-use intensity (EUI) (kWh/sqft/yr) by dividing the annual consumption by the square footage of the building. Figure 3 shows the electricity EUI of the 49 WCCUSD school buildings. Interestingly, Downer school is not in the lead in terms of the intensity, which is understandable considering its large area (121,086 sqft; elementary school median is 41,742 sqft). The five high schools still show relatively high electricity intensities.

Hercules Elementary School has the highest intensity of 7.64 kWh/sqft/yr. Further investigation is necessary to determine the cause of the high intensity of Hercules Elementary School.

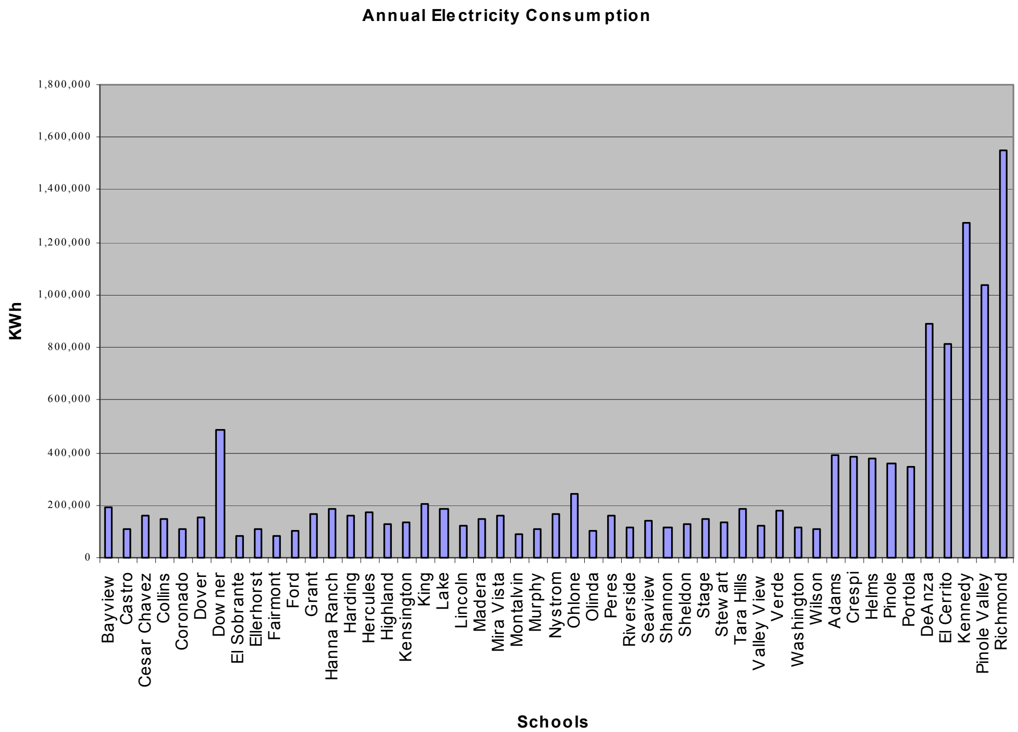

Figure 1. Annual electricity consumption for schools in the West Contra Costa Unified School District. The ten schools on the right are five middle schools followed by five high schools; all others are elementary schools.

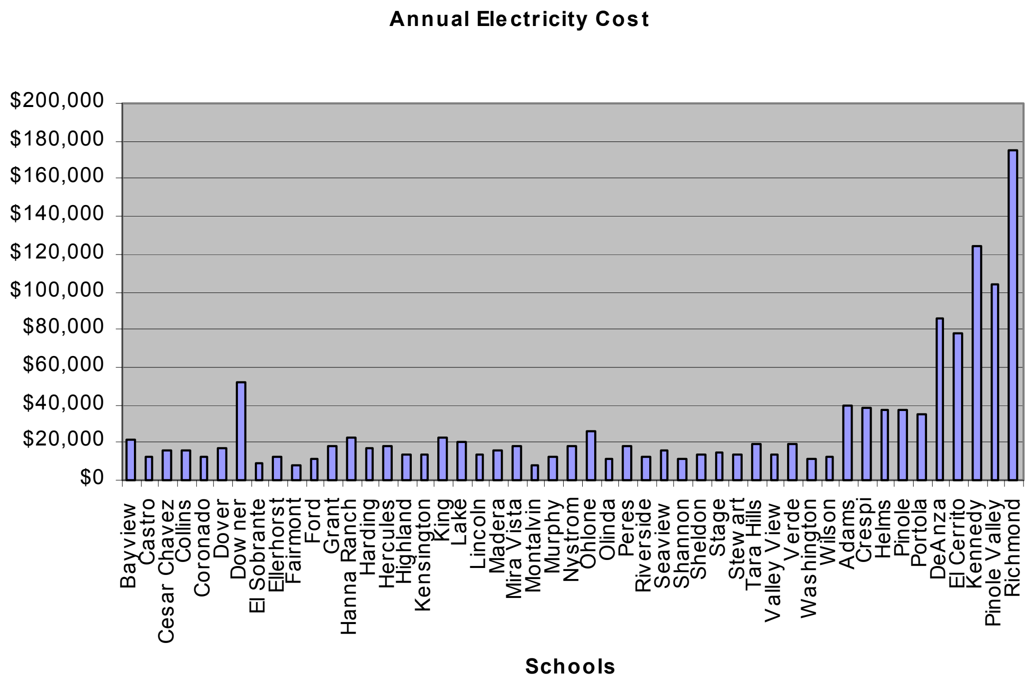

Figure 2. Annual electricity cost for WCCUSD schools

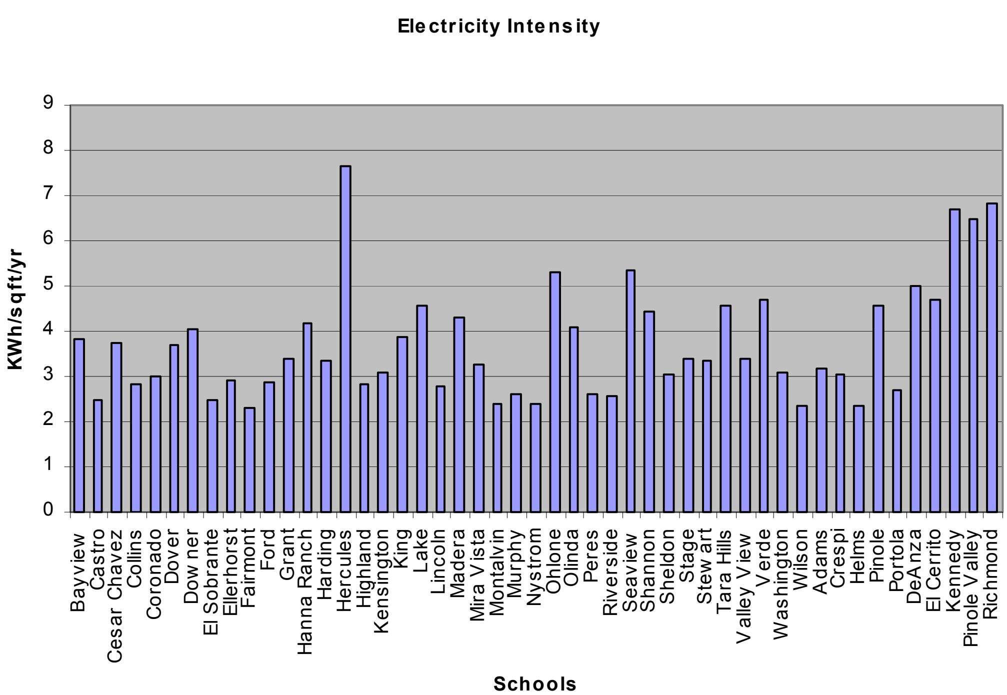

Figure 3. Electricity Intensity

Benchmarking can be performed on many different target groups. The easiest one is to compare within the sample group itself. Median values for the WCCUSD schools were used for this purpose by PG&E (2000) and will be used in this report. Table 1 shows the median values of electricity data for different types of schools within WCCUSD. Because each school shows a different characteristic following its category (elementary, middle and high), it is desirable to select the median value at each category as the target value. For example, elementary schools can use the median electricity EUI of 3.342 kWh/sqft/yr electricity intensity as the target value for electricity conservation measures. Half of the schools will have higher intensity values than the target value and significant savings can be achieved if they are brought down to the target value. Figure 4 shows hypothetical savings for elementary schools and Figure 5 shows savings relative to the median for secondary schools. The middle and the high schools are subject to separate median target values, as shown in Table 1.

Table 1. Median electricity data for the WCCUSD school groups

School category	Number of schools	Median area sqft	Median annual consumption KWh	Electricity Intensity KWh/sqft/yr	Median unit cost per KWh	Median annual cost
WCCUSD elementary	39	41,742	138,026	3.342	$0.108	$15,170
WCCUSD middle	5	125,000	375,653	3.053	$0.101	$37,734
WCCUSD high	5	177,762	1,039,381	6.459	$0.097	$103,819
WCCUSD total	49	43,541	159,362	3.369	$0.107	$16,896

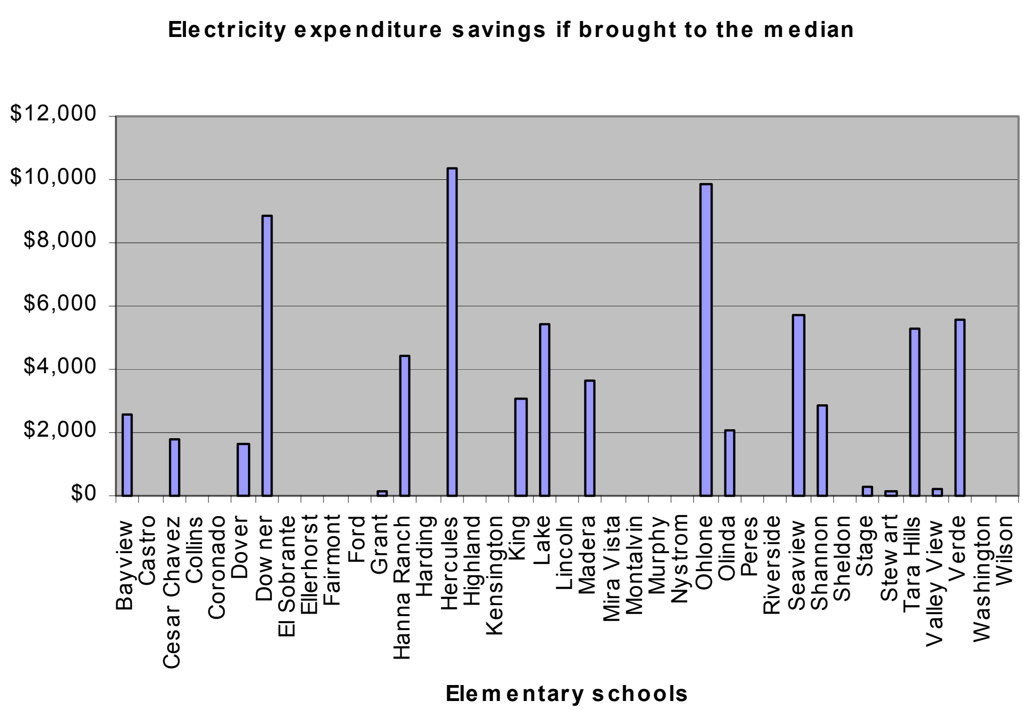

Figure 4. Elementary school savings in electricity if the EUI for each school with an EUI higher than the median value for all WCCUSD elementary schools is brought down to the median.

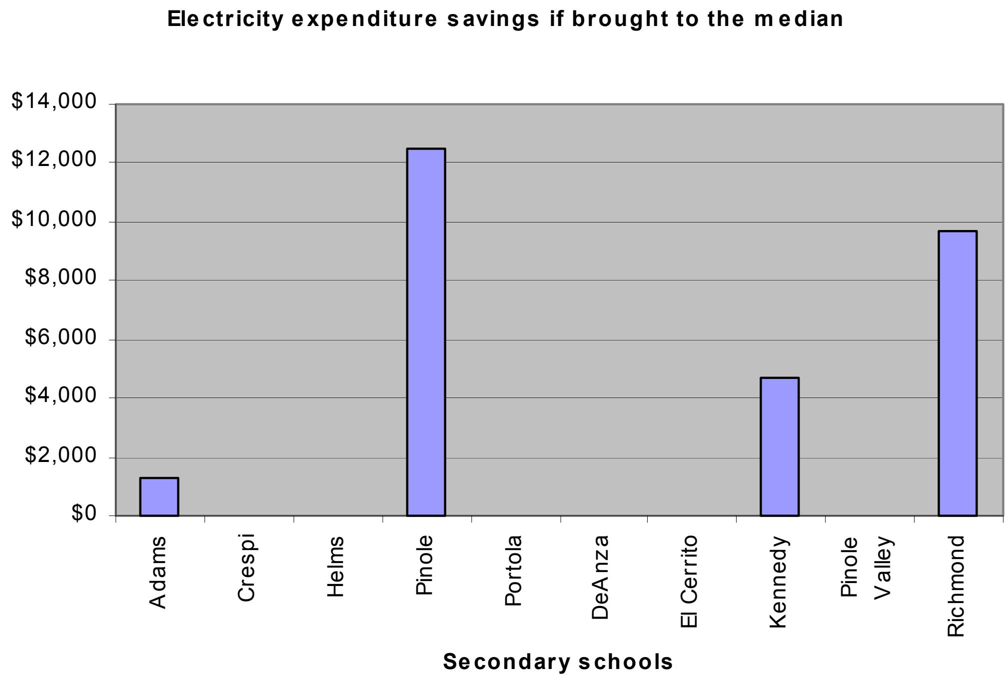

Figure 5. Secondary school savings in electricity if the EUI is brought to the median for elementary schools

Though convenient, the median value analysis is a simple arithmetic expression, which fails to account for the nature of the energy consumption and fails to spotlight the actual means of implementing energy conservation measures. It also fails to provide the insight into the EUI of the sample group relative to other groups, within the region or nationally. For a more detailed scientific analysis, it is necessary to have the portfolio of the energy consuming equipment (lighting, fan, chiller, etc.) for each school, and to know how they are operated (operation schedule, control logic, etc.). In addition to this static information, it is often necessary to have the time series submetered data (dynamic information) to keep track of the usage of major end-use equipment. It is desirable to observe malfunctions or inefficient operation of the equipment, either due to poor maintenance or inefficient implementation of control logic.

Peak demand data are available for some WCCUSD schools, but other electricity load characteristics are not available at this point. However, regional and the national electricity consumption profiles by end use will give a clue of how electricity is typically consumed in schools. Figure 6 shows school electricity consumption by end use for schools in PG&E's service territory, based on survey data (PG&E 1999). Figure 7 shows the national trend, from CBECS data. CBECS data include all schools; in the future, schools will be distinguished by size and ownership to separate K-12 facilities. From the figures, it is evident that lighting consumes most of the electricity, followed by cooling and ventilation. Compared to the national average, schools in PG&E's service territory spend less electricity in lighting but more on cooling and ventilation. Thus a reasonable energy saving measure will first target a reduction in the lighting load and then improve the efficiency of HVAC equipment and operation without compromising the comfort of the teaching environment.

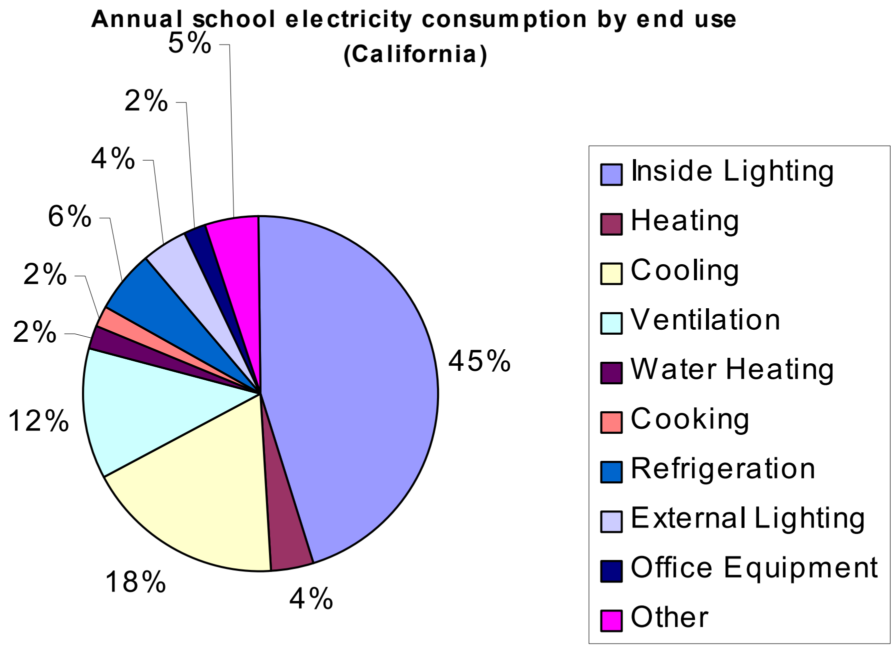

Figure 6. Annual electricity consumption by end use, for schools in the PG&E service territory. Consumption percentages are assumed to be equal to sales percentages reported in PG&E (1999)

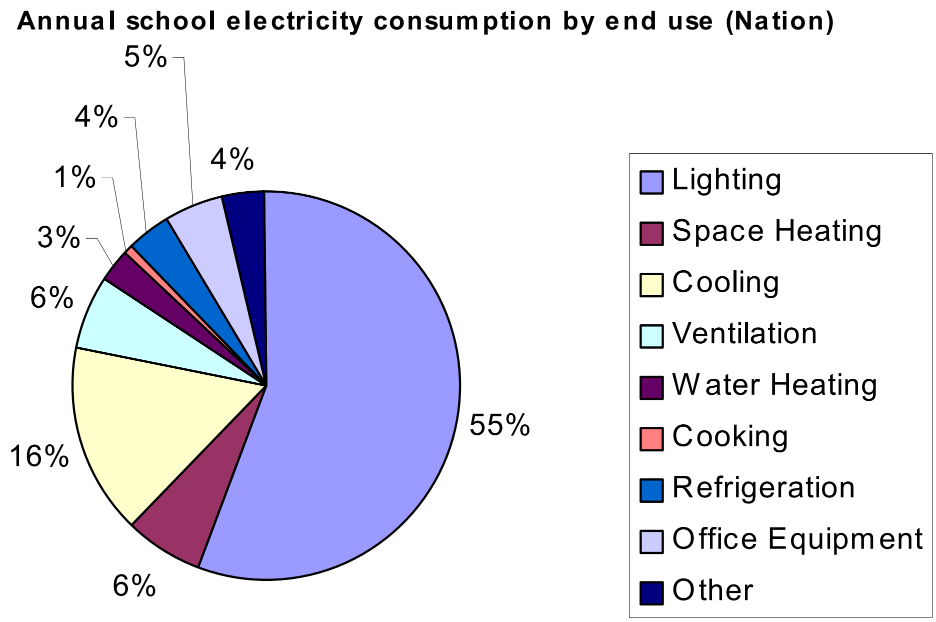

Figure 7. Annual electricity consumption by end use, based on national data for schools of all levels.

It is also helpful to compare energy-use intensities of the WCCUSD schools to those of the region and the nation. Table 2 shows the average electricity data for different school groups. The table shows the WCCUSD schools have lower EUIs compared to the regional (PG&E service territory) or nation averages. Other factors such as climate, hours of operation, and the number of students per facility need to be considered. California schools have a lower electricity intensity compared to the national average, which is demographically influenced by the hot and humid South. Within California. WCCUSD is located in the moderate climate 'Hill' area, according to the designation by PG&E (PG&E classified four climate regions in California: Desert/Mountain (extremely hot), Valley (hot), Hill (moderate) and Coastal (cool). Contra Costa County straddles two California climate zones, CZ3 and CZ12; the western part of the county and all WCCUSD schools are in CZ3.

Table 2. Average electricity data for different school groups

School category	Number of schools	Average area sqft	Average annual consumption KWh	Electricity Intensity KWh/sqft/yr	Average unit cost per KWh	Average annual cost
WCCUSD elementary	39	43,690	150,187	3.514	$0.109	$16,300
WCCUSD middle	5	122,530	369,520	3.167	$0.102	$37,685
WCCUSD high	5	185,657	1,112,791	5.940	$0.101	$113,506
WCCUSD total	49	66,222	270,793	3.726	$0.107	$28,401
PG&E service territory	4,700	31,270	213,000	6.82	$0.105	$22,365
Nation	309,000	25,100	210,000	8.41	$0.080	$16,700

To normalize the heating or cooling energy consumption due to the weather effect, degree-day methods are often used. Deviation from the design temperature is multiplied by the number of days to obtain degree-days, for either cooling or heating. Heating energy is normalized by dividing by heating degree-days and cooling energy by cooling degree-days. However, it is important to normalize the portion of energy used for heating or cooling only, because other portions of energy such as lighting cannot be normalized based on degree-days. Degree-day normalization is not necessary when the sample group is located within a single climate zone. Because, the WCCUSD schools are geographically located closely and end-use data are not available, degree-day normalization cannot be performed at this stage.

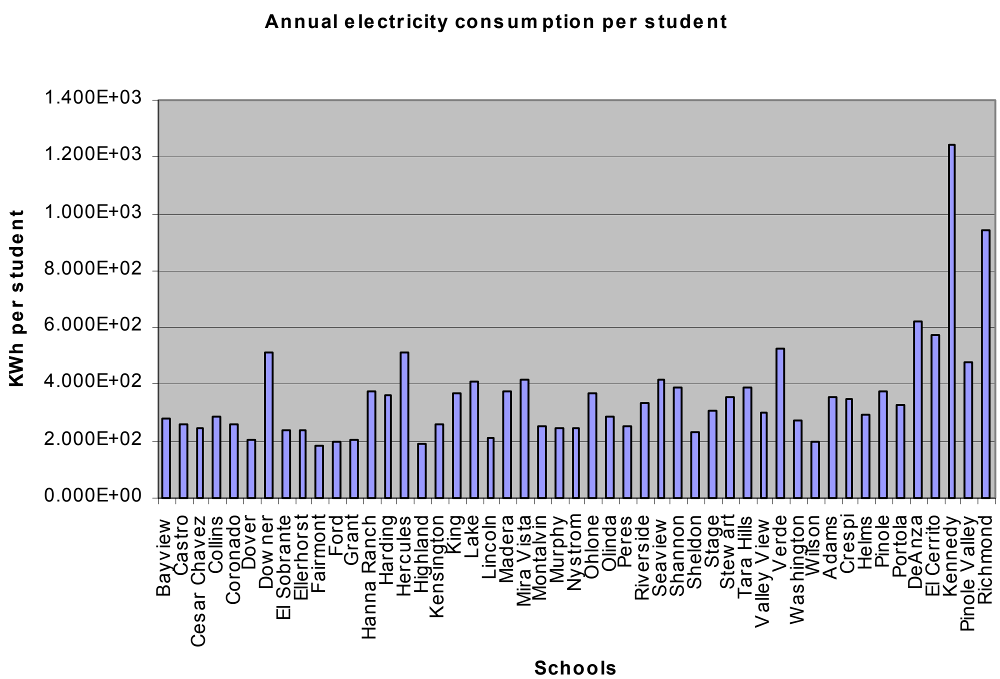

Figure 8. Annual electricity consumption per student

Other normalizations can include the number of occupants, including students, teachers and staff, and the hour of operation. Although the number of occupants is usually proportional to the square footage, it is not always the case. For example, a school with a larger area but a smaller number of students may show an energy intensity (normalized by area) comparable to other schools but a larger energy intensity per student. Downer Elementary School in WCCUSD is an example. It originally was designed as a junior high school but was converted to an elementary school. With the area of 121,086 sqft, it is three times larger than the average elementary school (average: 43,690 sqft) but it schools only 957 students, less than two times the elementary school average (499).

Figure 8 shows the annual electricity consumption per student. Ideally the consumption should be normalized based on the number of school occupants, including students, teachers and staff. However, at the time of writing this report, the number of other occupants except students was not known. As expected, Downer Elementary School shows one of the highest values for electricity consumption per capita among the elementary schools. Hercules and Verde are also among the top group. The high consumption of Kennedy and Richmond High Schools is also notable.

Gas Analysis

A similar analysis can be performed on the gas data. Figure 9 shows the annual gas consumption of the WCCUSD schools. Figure 10 is the resulting expenditure. As in the case of electricity consumption, secondary schools show larger amounts of gas consumption compared to the elementary schools. Pinole Middle School is one exception; its gas consumption is small and comparable to that of elementary schools. Downer Elementary School is also a notable exception: its consumption is second only to El Cerrito High School. In general, it is reasonable for the secondary schools to show higher amounts of gas usage because they are bigger both in building size and number of students. As mentioned before, Downer was originally built as a junior high school and is larger than other elementary schools. It also has a central heating system, whereas other elementary schools have individual gas furnaces in each classroom. The central heating system may be low in energy efficiency compared to the gas furnaces. Further investigation is necessary to point out the causes of high gas usage and to come up with energy saving measures.

Figure 11 shows the gas intensity (therm/sqft/yr). In terms of gas intensity, the elementary and the secondary schools are on the same order of magnitude. Interestingly, two elementary schools, Downer and Murphy, show the highest intensities, not the high schools. Even though Downer's huge area contributed to reducing the energy-use intensity relative to other elementary schools, its intensity is still the largest among all schools and marks Downer as a prime candidate for further study of energy consumption.

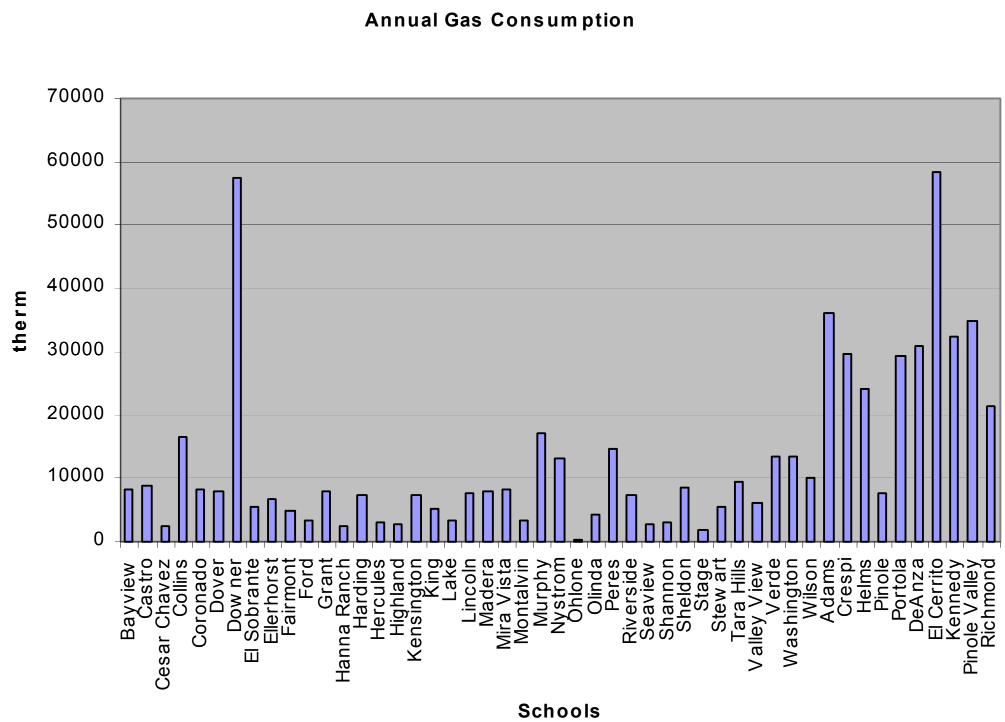

Figure 9. Annual gas consumption

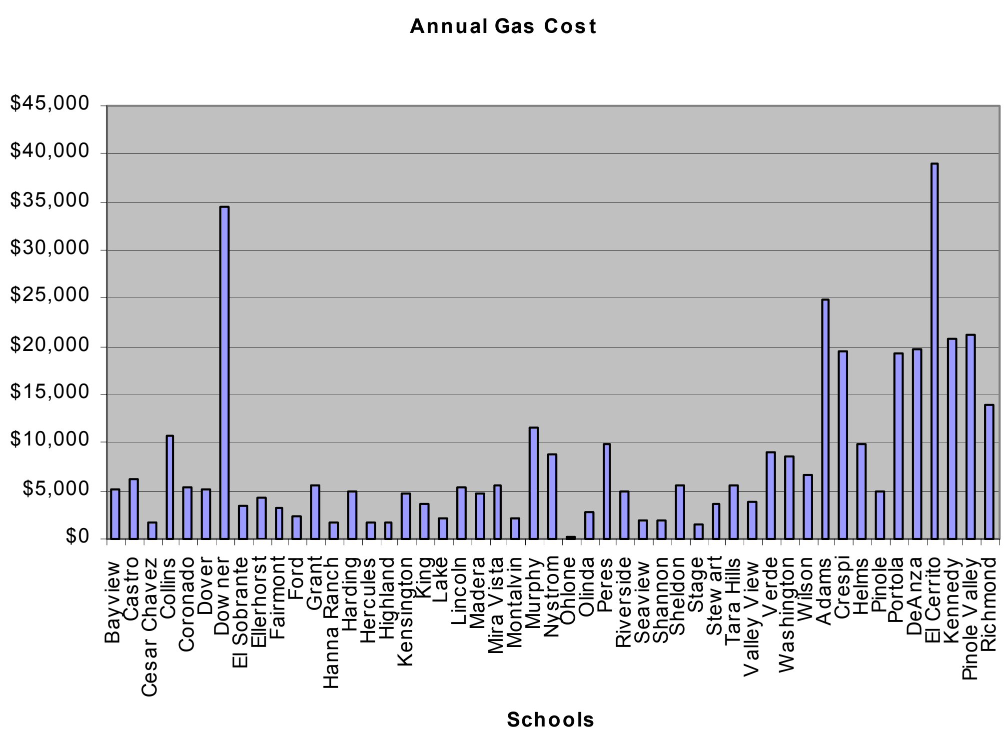

Figure 10. Annual gas cost

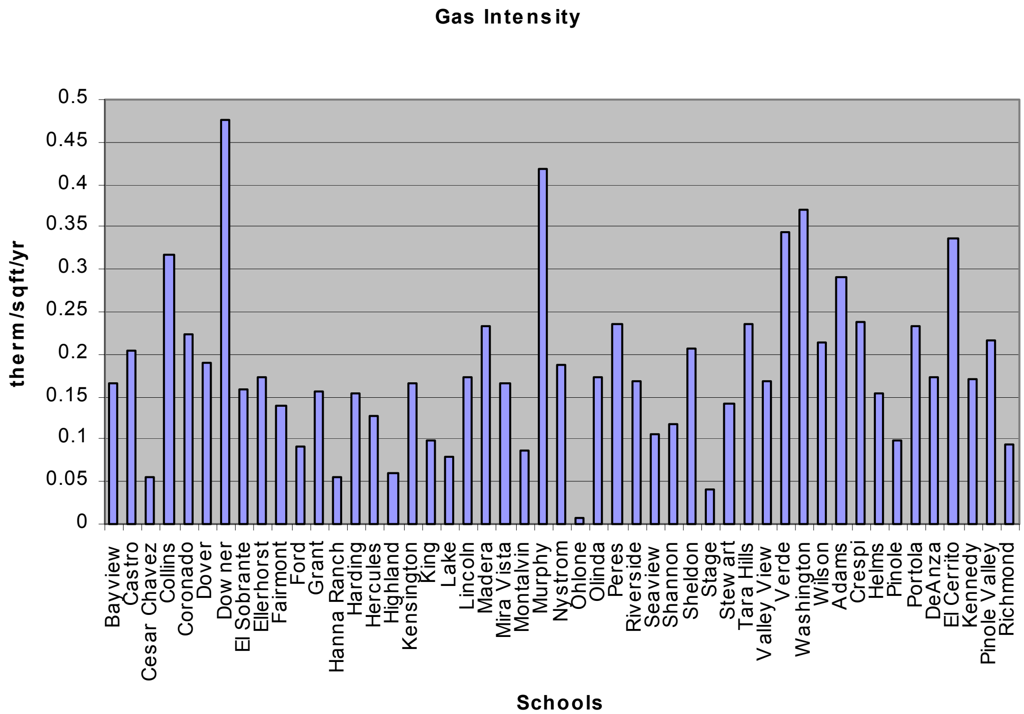

Figure 11. Gas Intensity

A simple median analysis can also be performed on the gas data. Table 3 shows the median gas data for the WCCUSD schools. Figure 12 and 13 shows the potential savings if each school is brought to the median gas intensity of each group.

Table 3. Median gas data for the WCCUSD school groups

School category	Number of schools	Median area sqft	Median annual consumption therm	Gas Intensity therm/sqft/yr	Median unit cost per therm	Median annual cost
WCCUSD elementary	39	41,742	7,281	0.1667	$0.666	$4,812
WCCUSD middle	5	125,000	29,437	0.2321	$0.655	$19,275
WCCUSD high	5	177,762	32,410	0.1743	$0.633	$20,735
WCCUSD total	49	43,541	7,840	0.1690	$0.664	$5,219

Gas is mainly used for heating purposes. Figure 14 shows gas end use for schools in the PG&E service territory . Figure 15 shows end-use data at the national level; as with electricity data, national end-uses are for all schools and have not been analyzed to separate K-12 facilities . From the figures, it is clearly seen that gas consumption is dominated by space heating, followed by domestic water heating. Cooking accounts for a relatively small portion of the gas end use.

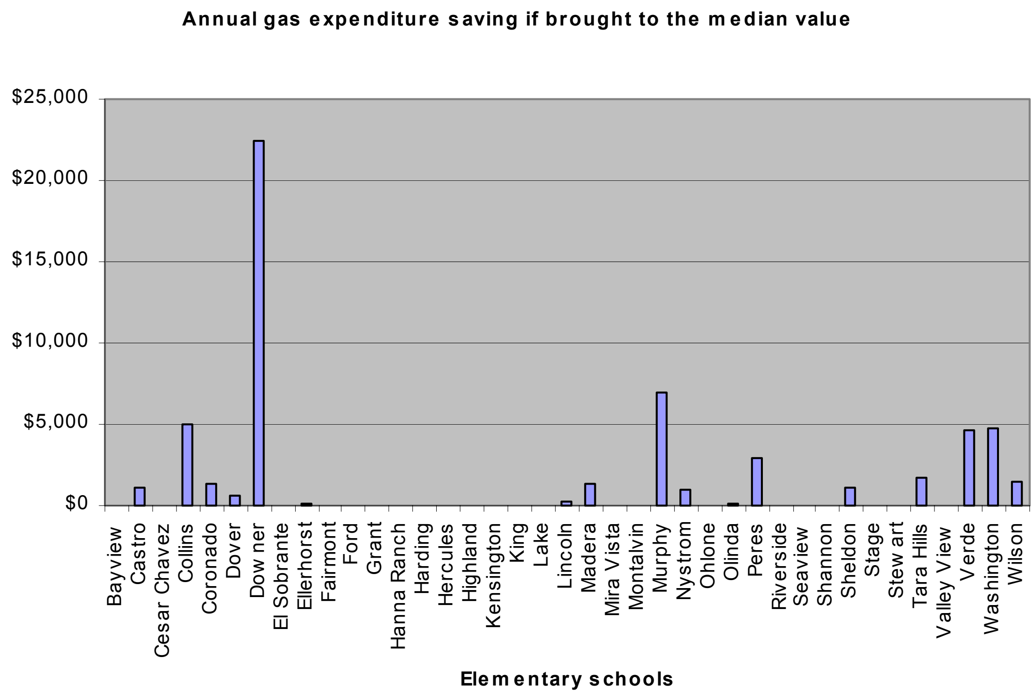

Figure 12. Elementary school savings in gas if the gas intensity is brought to their median value

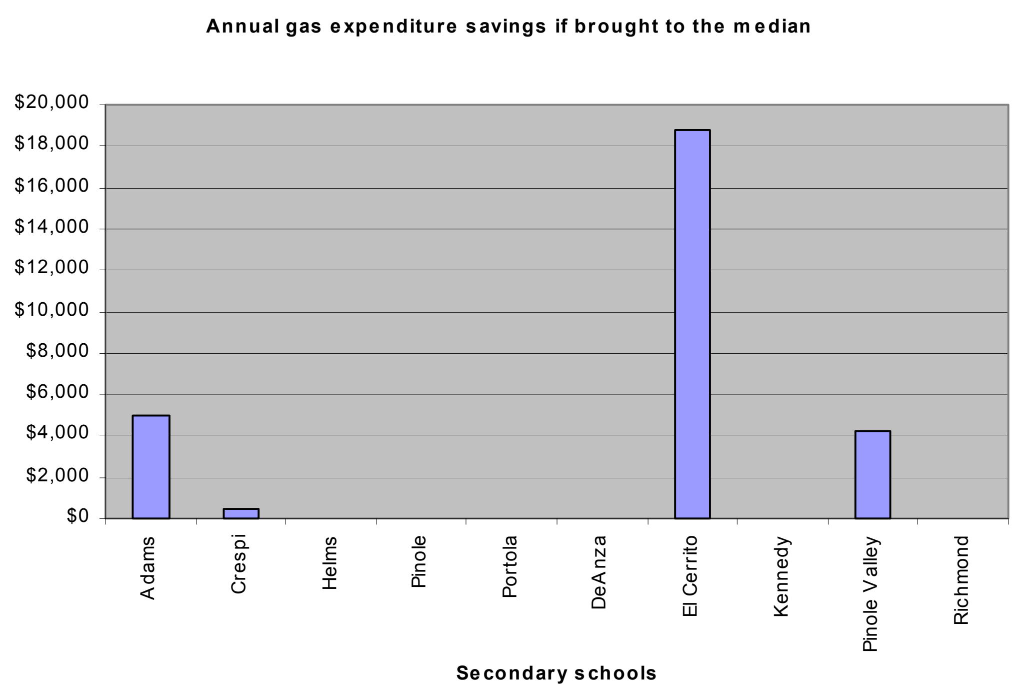

Figure 13. Secondary school savings in gas if the gas intensity is brought to their median value

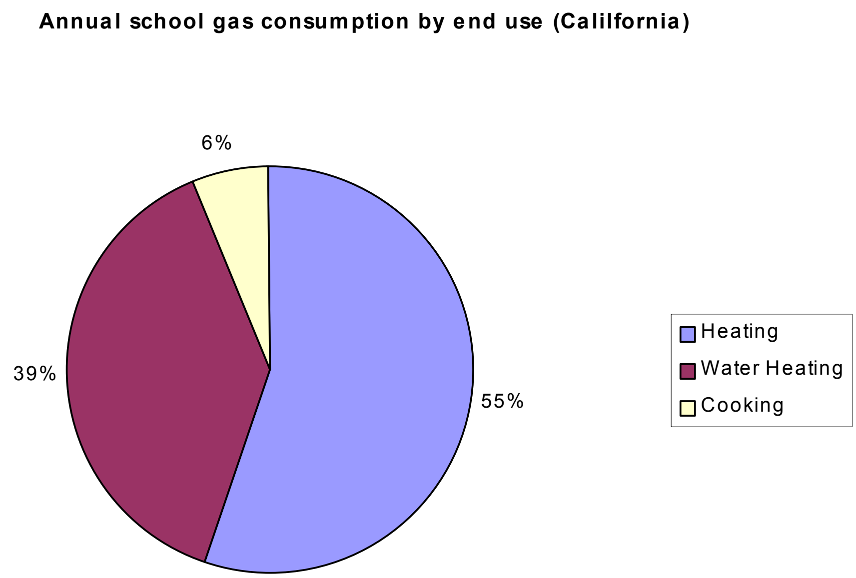

Figure 14. Annual gas consumption by end use, for schools in the PG&E service territory

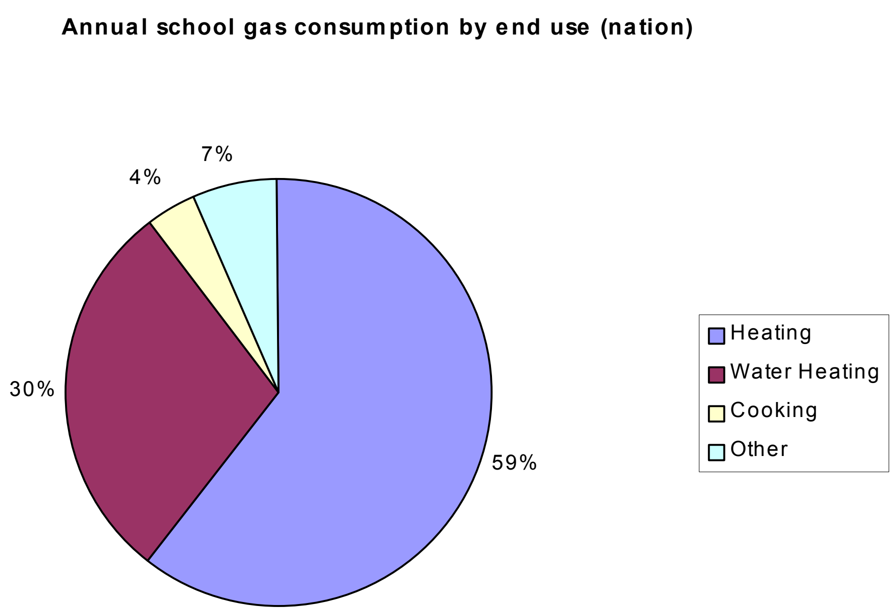

Figure 15. Annual gas consumption by end use, based on national data for schools of all levels

Benchmarking with the regional and national gas averages is also required to access the energy-use intensity of the WCCUSD schools. Table 4 shows the average data for different school groups. In terms of gas intensity, the WCCUSD schools fall below the average school in PG&E's service territory. The gas intensity is also much lower than the nation average. However this comparison needs to be cautioned, because the national average is affected by the heavy gas users in Northeast and Midwest due to the severe winter weather. For a fair comparison, normalization based on climate, such as heating degree-days, is necessary.

Table 4. Average gas data for different school groups

School category	Number of schools	Average area sqft	Average annual consumption therm	gas Intensity therm/sqft/yr	Average unit cost per therm	Average annual cost
WCCUSD elementary	39	43,690	8,382	0.1766	$0.679	$5,470
WCCUSD middle	5	122,530	25,416	0.2023	$0.605	$15,723
WCCUSD high	5	185,657	35,614	0.1987	$0.620	$22,897
WCCUSD total	49	66,222	12,899	0.1815	$0.665	$8,294
PG&E service territory	4,700	31,270	11,000	0.3525	$0.640	$7,055
Nation	309,000	25,100	10,600	0.4230	$0.519	$5,500

Figure 16 shows the annual gas consumption per student. Downer Elementary School consumes the most among all the schools.

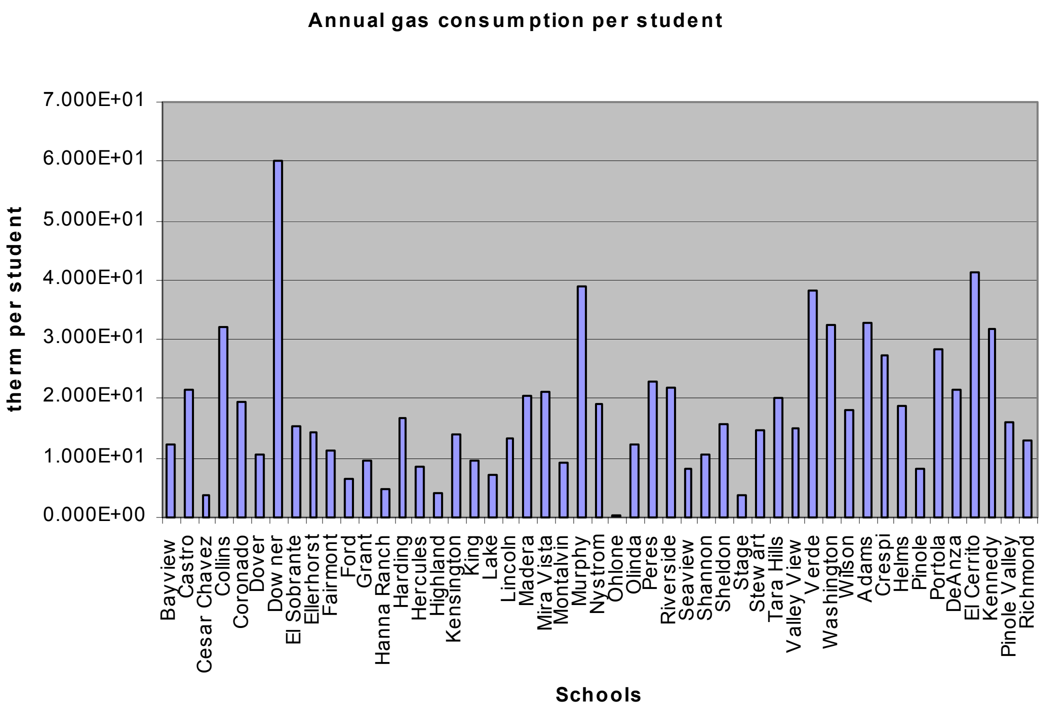

Figure 16. Annual gas consumption per student

Total Energy Use

A complete energy analysis needs to take account of the consumption of both electricity and gas. Each school can have a different variety of equipment. For example, if a school has an electric heater to produce hot water, the school will show relatively low gas consumption and gas-use intensity. Its electricity consumption needs to be considered before any conclusion is made. Figure 17 shows the annual total energy consumption of the WCCUSD schools, converted to BTU. For conversion, 1 KWh = 3412 BTU and 1 therm = 1.0e5 BTU are used. As expected, high schools consume more energy than middle schools, which in turn use more than elementary schools. Downer Elementary School is the exception, equaling the high schools in annual energy consumption. Its relatively high amount of gas consumption is particularly notable.

Figure 18 shows the resulting dollar amount spent each year to pay the energy bill. The general trend is similar to Figure 15, but the proportion of gas is shrunk when converted to the dollar amount, reflecting the relatively high electricity cost. More emphasis needs to be placed on reducing electricity consumption to realize substantial dollar savings.

Figure 19 shows the total energy intensity (BTU/sqft/yr). There doesn't seem to be a general trend. The highest is Downer Elementary School, as expected. The relatively high gas intensity of Murphy Elementary School and the high electricity intensity of Hercules Elementary School are notable.

Figure 20 shows the total energy consumption per student. A student in Downer Elementary School consumes the most, followed by a student in Kennedy High School.

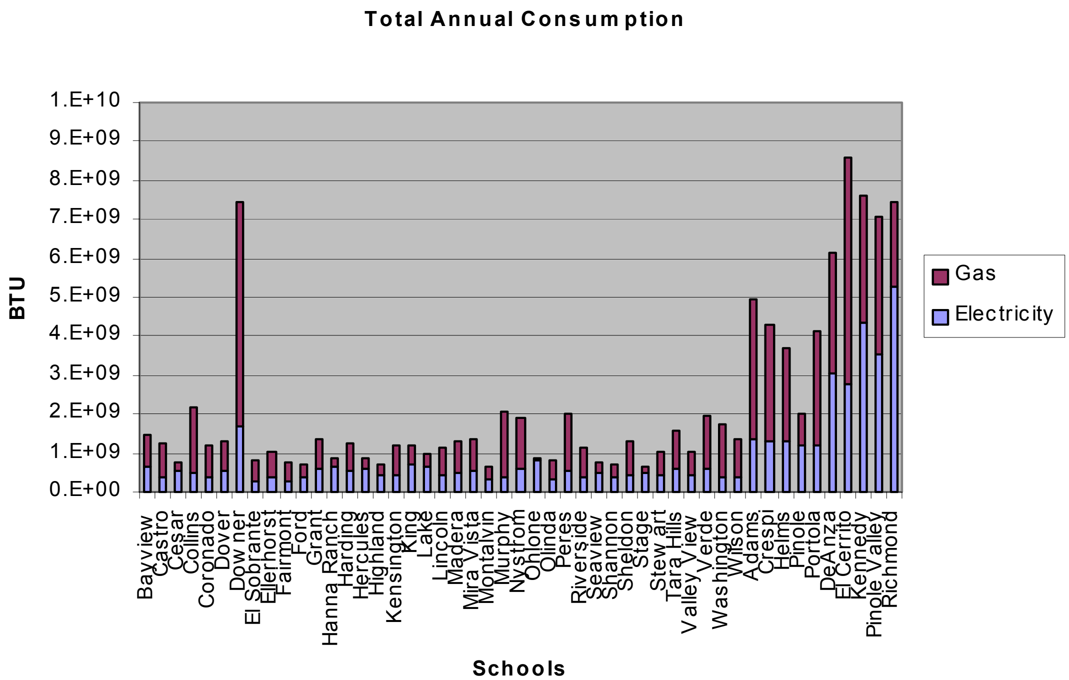

Figure 17. Total annual energy consumption

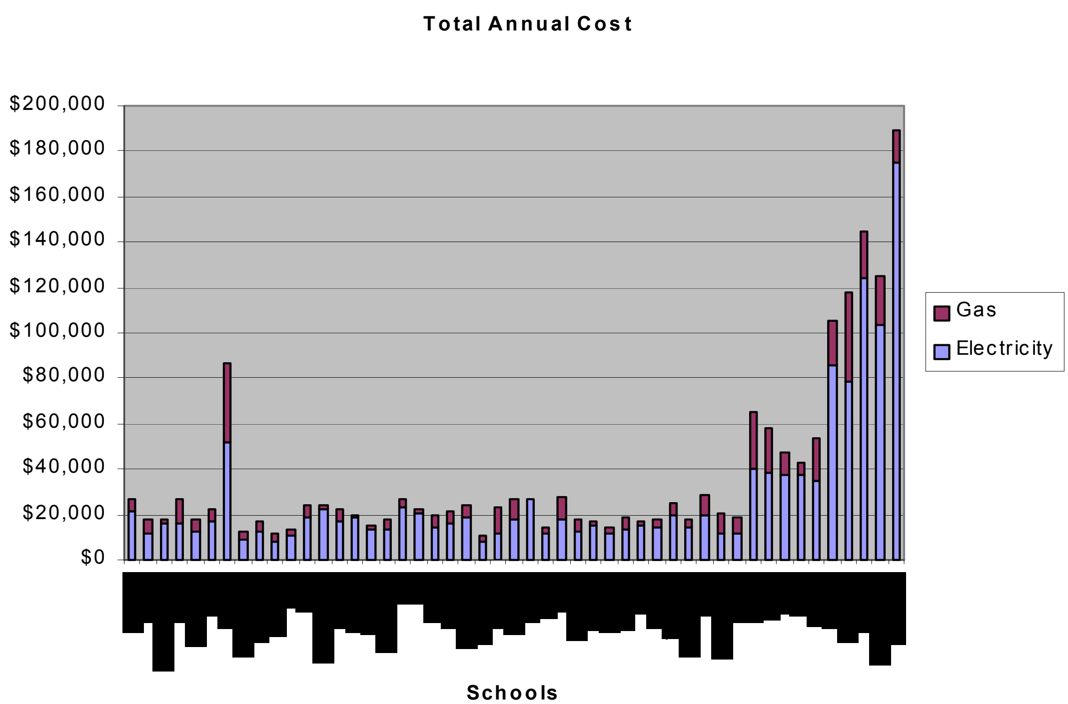

Figure 18. Total annual energy cost

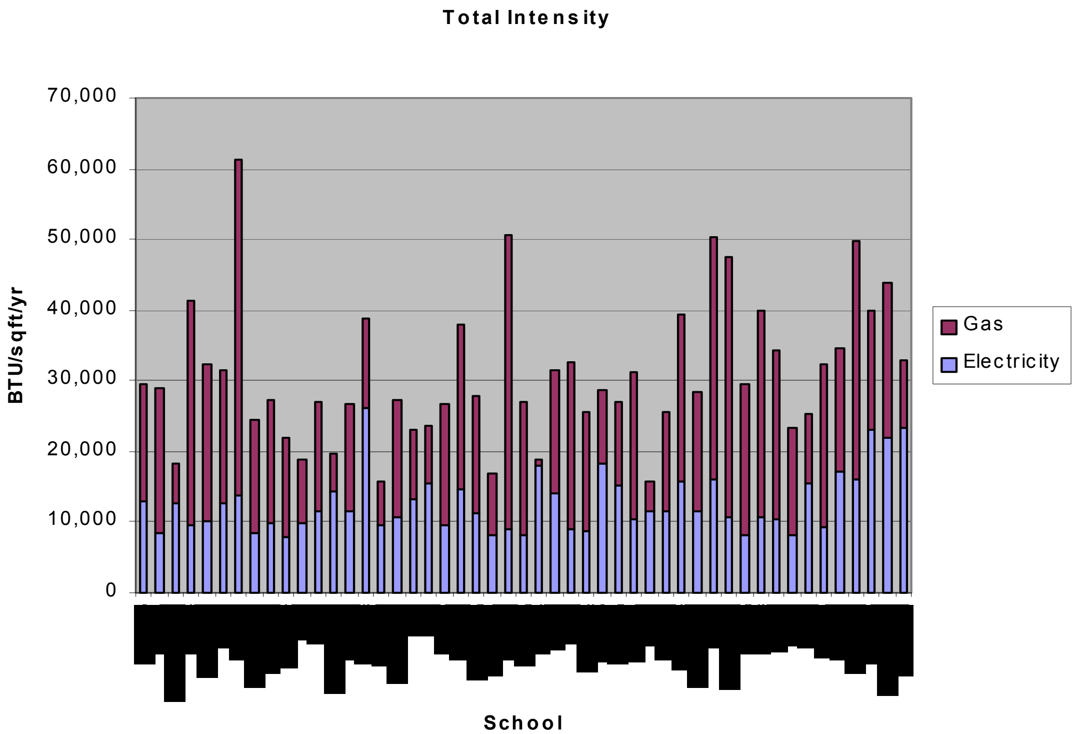

Figure 19. Total energy intensity

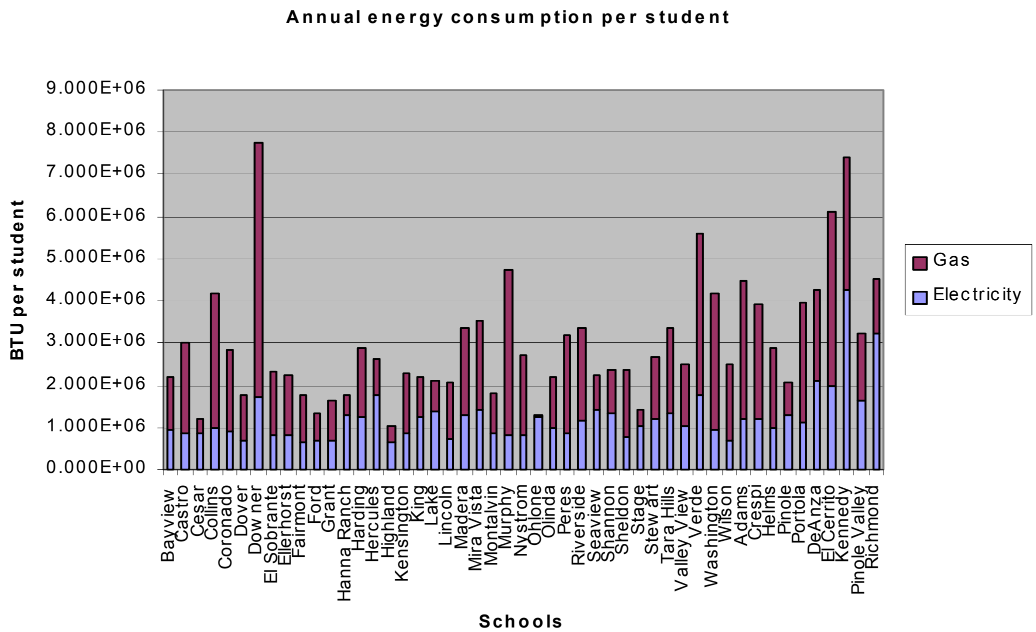

Figure 20. Annual energy consumption per student

Future Work

Work in the near future will include the collection and analysis of more information about each WCCUSD school, including whether each has a pool, a kitchen, air conditioning, and such energy-intensive equipment as kilns. Also, operating hours and seasonal usage (i.e., year-round operation) will be collected, along with local climate data. The schools will be rated with EPA's Energy Star on-line evaluation tool. Peak load data, where available, will be compared with energy consumption to establish load factors. National (CBECS) data will be analyzed to separate K-12 schools from all others, in order to sharpen the comparison with WCCUSD schools.

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Appendix

Table A1. WCCUSD school electricity/gas raw data

			Electricity						Gas				Total		
School	Type	Area	Annual Usage	Unit Cost	Annual Cost	Electricity Intensity	Max. Demand	Power Density	Annual Usage	Unit Cost	Annual Cost	Gas Intensity	Annual Cost	Unit Cost	Energy Intensity
		Sq. foot	KWh	per KWh		kWh/sqft/yr	kW	W/sqft	therm	per therm		therm/sqft/yr		per sq. ft	BTU/sqft/yr
Bayview	ES	49,781	189,559	$0.112	$21,197	3.808	145	2.913	8216	0.635	$5,219	0.165	$26,416	$0.53	29,501
Castro	ES	43,125	106,468	$0.112	$11,887	2.469	0	0.000	8823	0.692	$6,109	0.205	$17,996	$0.42	28,885
Cesar Chavez	ES	43,063	161,242	$0.102	$16,374	3.744	75	1.742	2335	0.771	$1,800	0.054	$18,174	$0.42	18,202
Collins	ES	52,051	146,160	$0.111	$16,220	2.808	70	1.345	16494	0.643	$10,613	0.317	$26,833	$0.52	41,272
Coronado	ES	37,467	111,812	$0.113	$12,656	2.984	61	1.628	8347	0.634	$5,295	0.223	$17,951	$0.48	32,464
Dover	ES	41,050	151,807	$0.111	$16,896	3.698	0	0.000	7800	0.666	$5,191	0.190	$22,087	$0.54	31,623
Downer	ES	121,086	488,185	$0.106	$51,681	4.032	228	1.883	57536	0.601	$34,560	0.475	$86,241	$0.71	61,277
El Sobrante	ES	33,648	83,781	$0.107	$8,930	2.490	0	0.000	5370	0.653	$3,509	0.160	$12,439	$0.37	24,457
Ellerhorst	ES	37,905	109,939	$0.117	$12,818	2.900	70	1.847	6592	0.664	$4,380	0.174	$17,198	$0.45	27,290
Fairmont	ES	34,536	80,220	$0.101	$8,137	2.323	0	0.000	4845	0.658	$3,189	0.140	$11,326	$0.33	21,957
Ford	ES	36,272	103,923	$0.106	$11,027	2.865	76	2.095	3306	0.725	$2,398	0.091	$13,425	$0.37	18,893
Grant	ES	50,211	169,211	$0.109	$18,465	3.370	81	1.613	7840	0.699	$5,484	0.156	$23,949	$0.48	27,116
Hanna Ranch	ES	44,195	185,120	$0.119	$22,064	4.189	174	3.937	2410	0.697	$1,680	0.055	$23,744	$0.54	19,749
Harding	ES	47,690	159,362	$0.108	$17,140	3.342	0	0.000	7281	0.664	$4,837	0.153	$21,977	$0.46	26,672
Hercules	ES	22,858	174,720	$0.105	$18,316	7.644	0	0.000	2911	0.589	$1,716	0.127	$20,032	$0.88	38,823
Highland	ES	45,007	127,462	$0.107	$13,622	2.832	0	0.000	2693	0.674	$1,814	0.060	$15,436	$0.34	15,649
Kensington	ES	43,473	134,502	$0.100	$13,466	3.094	0	0.000	7243	0.664	$4,812	0.167	$18,278	$0.42	27,220
King	ES	52,956	203,910	$0.113	$23,117	3.851	132	2.493	5214	0.695	$3,622	0.098	$26,739	$0.50	22,988
Lake	ES	40,908	186,313	$0.110	$20,483	4.554	103	2.518	3245	0.684	$2,220	0.079	$22,703	$0.55	23,477
Lincoln	ES	43,541	120,560	$0.117	$14,078	2.769	84	1.929	7540	0.71	$5,353	0.173	$19,431	$0.45	26,767
Madera	ES	33,929	145,655	$0.112	$16,354	4.293	86	2.535	7937	0.603	$4,789	0.234	$21,143	$0.62	38,045
Mira Vista	ES	49,631	162,634	$0.113	$18,366	3.277	100	2.015	8268	0.666	$5,505	0.167	$23,871	$0.48	27,843
Montalvin	ES	37,947	90,480	$0.103	$8,280	2.384	0	0.000	3326	0.628	$2,088	0.088	$10,368	$0.27	16,903
Murphy	ES	41,135	107,027	$0.111	$11,893	2.602	7	0.170	17161	0.677	$11,624	0.417	$23,517	$0.57	50,599
Nystrom	ES	70,172	168,381	$0.106	$17,898	2.400	76	1.083	13171	0.67	$8,820	0.188	$26,718	$0.38	26,959

Ohlone	ES	45,561	241,618	$0.110	$26,481	5.303	0	0.000	300	1.04	$312	0.007	$26,793	$0.59	18,758
Olinda	ES	25,129	103,082	$0.108	$11,172	4.102	0	0.000	4376	0.66	$2,888	0.174	$14,060	$0.56	31,415
Peres	ES	62,322	162,080	$0.112	$18,155	2.601	103	1.653	14749	0.666	$9,828	0.237	$27,983	$0.45	32,542
Riverside	ES	43,901	113,557	$0.112	$12,771	2.587	66	1.503	7402	0.679	$5,024	0.169	$17,795	$0.41	25,689
Seaview	ES	25,871	138,026	$0.111	$15,311	5.335	1	0.039	2737	0.719	$1,968	0.106	$17,279	$0.67	28,788
Shannon	ES	25,598	113,050	$0.104	$11,812	4.416	0	0.000	3031	0.671	$2,034	0.118	$13,846	$0.54	26,914
Sheldon	ES	41,742	127,777	$0.104	$13,261	3.061	0	0.000	8634	0.653	$5,637	0.207	$18,898	$0.45	31,132
Stage	ES	42,382	144,635	$0.105	$15,170	3.413	0	0.000	1743	0.849	$1,480	0.041	$16,650	$0.39	15,760
Stewart	ES	39,487	133,031	$0.106	$14,081	3.369	0	0.000	5558	0.672	$3,736	0.141	$17,817	$0.45	25,574
Tara Hills	ES	39,943	183,120	$0.107	$19,363	4.585	106	2.654	9446	0.597	$5,643	0.236	$25,006	$0.63	39,296
Valley View	ES	35,998	122,175	$0.115	$14,087	3.394	91	2.528	6094	0.642	$3,911	0.169	$17,998	$0.50	28,512
Verde	ES	38,837	182,560	$0.105	$19,199	4.701	88	2.266	13330	0.671	$8,940	0.343	$28,139	$0.72	50,366
Washington	ES	36,670	113,910	$0.102	$11,564	3.106	0	0.000	13573	0.635	$8,616	0.370	$20,180	$0.55	47,616
Wilson	ES	46,846	110,250	$0.108	$11,917	2.353	0	0.000	10003	0.668	$6,678	0.214	$18,595	$0.40	29,385
Adams	MS	123,803	390,377	$0.103	$40,016	3.153	166	1.341	35958	0.691	$24,861	0.290	$64,877	$0.52	39,806
Crespi	MS	125,000	381,600	$0.100	$38,332	3.053	205	1.640	29700	0.66	$19,604	0.238	$57,936	$0.46	34,179
Helms	MS	158,682	375,653	$0.100	$37,712	2.367	189	1.191	24285	0.369	$9,862	0.153	$47,574	$0.30	23,384
Pinole	MS	78,313	356,920	$0.106	$37,734	4.558	154	1.966	7699	0.651	$5,015	0.098	$42,749	$0.55	25,386
Portola	MS	126,852	343,048	$0.101	$34,633	2.704	159	1.253	29437	0.655	$19,275	0.232	$53,908	$0.42	32,436
DeAnza	HS	177,762	889,516	$0.097	$85,956	5.004	470	2.644	30976	0.633	$19,621	0.174	$105,577	$0.59	34,504
El Cerrito	HS	173,259	811,517	$0.097	$78,485	4.684	293	1.691	58347	0.667	$38,929	0.337	$117,414	$0.68	49,662
Kennedy	HS	189,841	1,274,853	$0.097	$124,254	6.715	427	2.249	32410	0.64	$20,735	0.171	$144,989	$0.76	39,992
Pinole Valley	HS	160,915	1,039,381	$0.100	$103,819	6.459	461	2.865	34908	0.61	$21,310	0.217	$125,129	$0.78	43,739
Richmond	HS	226,510	1,548,689	$0.113	$175,014	6.837	677	2.989	21429	0.548	$13,892	0.095	$188,906	$0.83	32,796

Table A2. Student Enrollment Data

School	Type	Area		Student Enrollment		
		Sq. foot	Apr. 7, 2000	Oct. 20, 2000	Apr. 6, 2001	Average
Bayview	ES	49,781	693	663	667	674
Castro	ES	43,125	422	403	412	412
Cesar Chavez	ES	43,063	643	647	656	649
Collins	ES	52,051	529	501	509	513
Coronado	ES	37,467	441	415	421	426
Dover	ES	41,050	714	739	740	731
Downer	ES	121,086	946	966	959	957
El Sobrante	ES	33,648	350	346	358	351
Ellerhorst	ES	37,905	463	462	465	463
Fairmont	ES	34,536	448	423	415	429
Ford	ES	36,272	534	518	512	521
Grant	ES	50,211	852	822	823	832
Hanna Ranch	ES	44,195	500	493	494	496
Harding	ES	47,690	445	434	434	438
Hercules	ES	22,858	345	339	336	340
Highland	ES	45,007	685	678	668	677
Kensington	ES	43,473	527	510	524	520
King	ES	52,956	548	548	558	551
Lake	ES	40,908	445	456	469	457
Lincoln	ES	43,541	560	566	569	565
Madera	ES	33,929	387	387	384	386
Mira Vista	ES	49,631	371	404	396	390
Montalvin	ES	37,947	364	358	345	356
Murphy	ES	41,135	467	426	426	440
Nystrom	ES	70,172	695	698	686	693
Ohlone	ES	45,561	668	654	653	658
Olinda	ES	25,129	367	355	355	359
Peres	ES	62,322	633	649	640	641
Riverside	ES	43,901	340	340	332	337
Seaview	ES	25,871	339	321	333	331

Shannon	ES	25,598	297	275	295	289
Sheldon	ES	41,742	550	552	548	550
Stage	ES	42,382	466	473	473	471
Stewart	ES	39,487	371	377	383	377
Tara Hills	ES	39,943	477	471	459	469
Valley View	ES	35,998	407	410	413	410
Verde	ES	38,837	349	356	343	349
Washington	ES	36,670	395	421	437	418
Wilson	ES	46,846	565	542	547	551
Adams	MS	123,803	1,084	1,108	1,099	1,097
Crespi	MS	125,000	1,077	1,096	1,090	1,088
Helms	MS	158,682	1,208	1,331	1,310	1,283
Pinole	MS	78,313	942	963	953	953
Portola	MS	126,852	1,045	1,059	1,017	1,040
DeAnza	HS	177,762	1,429	1,473	1,413	1,438
El Cerrito	HS	173,259	1,363	1,473	1,394	1,410
Kennedy	HS	189,841	934	1,106	1,037	1,026
Pinole Valley	HS	160,915	2,160	2,219	2,123	2,167
Richmond	HS	226,510	1,582	1,722	1,627	1,644